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FPL '69

ANNUAL
REPORT
OF
RESEARCH
AT THE
FOREST
PRODUCTS
LABORATORY

FPL '69:

***ANNUAL
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LABORATORY***

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Foreword

With this report we end the decade that opened with glowing promises about the "Golden Sixties." The decade was marked by at least one truly spectacular development, the birth of a Cinderella industry of recent times—southern pine plywood. Yet on looking back, today's evaluation would probably be that the decade fell short of expectations, for many of the technological breakthroughs anticipated 10 years ago have not yet materialized.

The beginning of a new decade again invites prognostication. Today it appears that we can speak with much greater assurance of what lies ahead. It is now generally understood throughout the land that wood will continue to have an important role in the national economy and will contribute to the solution of some of the Nation's most urgent social and economic problems.

In research, we believe, technological developments will be pushed forward actively to meet those commitments, and new developments will serve to mechanize, automate, and generally improve the efficiency¹ of wood products manufacturing processes.

We know that housing will be big business in the United States and will provide growing markets for wood.

We know that our timber resources will be strained to the ultimate to meet the demands of the growing population and economy, requiring greater processing efficiency and fuller use of all wood resources.

We know that environmental considerations will affect all industrial harvesting and processing operations, adding great emphasis to full utilization to eliminate polluting residues.

This report indicates how our research program is responding to the Nation's important economic, social, and environmental problems through re-orientation that places great emphasis on housing, environment, and fuller timber utilization. While the goals can be simply stated, the research required to attain them becomes increasingly complex. Today entire systems are studied by teams of scientists having varieties of talents and specialties. Hence, you will find that FPL research studies reported here are less neatly cataloged by subject and discipline than before. The broad picture will be apparent only after the entire report has been perused.

We look forward to the decade of the '70's as one in which the environmental revolution will assign to wood its rightful place in this closed system which is our world. It is the only major renewable resource that can be grown, harvested, used, and disposed of in perpetuity, with a minimum of environmental disturbance.



H. O. FLEISCHER
Director



New facilities of FPL include the wood chemistry building in foreground which forms a U shape with an earlier completed laboratory-office building and pilot plant for fiber products research. At far left is the main building.

FPL '69 A Phase Completed

The year 1969 brought to completion the first phase of FPL's first major expansion in physical plant—providing new facilities second to none—since it had occupied its present headquarters in 1932. The third of three new buildings, a wood chemistry laboratory, came into use, and to mark the occasion, the largest delegation of Congress ever to visit FPL spent November 14 inspecting the new facilities and discussing the research program.

Members of the delegation were Cong. Robert W. Kastenmeier, representative of the Congressional district that includes Madison, and the delegation's leader; and Cong. John P. Saylor and George

A. Goodling of Pennsylvania, James A. McClure of Idaho, and John L. McMillan of South Carolina. Besides the new wood chemistry research laboratories they saw a pilot plant and laboratories for research in pulp, paper, and other wood fiber products. The pilot plant is especially outstanding, in that its superstructure consists mainly of commercial wood products brought into existence largely through FPL research—among them glued laminated arches, sandwich wall panels, paper-plastic-overlaid plywood, wood preservatives, and natural stain exterior finish.

The newest, the wood chemistry laboratory, will

FPL's research on low-cost housing, pollution, and more efficient use of wood generally was reviewed Nov. 14 by this Congressional delegation from Washington, D.C. Shown before a demonstration of low-cost housing research are, from left, Cong. John P. Saylor (R-Pa.), Cong. George A. Goodling (R-Pa.), Cong. James A. McClure (R-Idaho), Dr. H. O. Fleischer, director of the Laboratory, Cong. Robert W. Kastenmeier (D-Wis.), and Cong. John L. McMillan (D-S.C.).





L. O. Anderson, FPL architect-engineer, receives a Superior Service Award from Secretary of Agriculture Clifford M. Hardin at ceremonies in Washington, D.C., for his research contributions to low-cost housing for rural areas. M 136 581

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house research with missions vital to large segments of the forest products industry, notably plastics, synthetic fibers, and industrial chemicals. Special precise controls of temperature and humidity in some of the laboratories will enable highly sensitive analytical equipment, such as spectrophotometers and gas chromatographic apparatus, to function more precisely in research on unknown substances. Included is a laboratory designed to Atomic Energy Commission specifications for research

with radioactive substances, with special venting and hoods, stainless steel seamless benchtops, and strippable paint on walls and ceiling for safe disposal of radioactive substances. Other space is designed for high-pressure experiments with hydrogen, nitrogen and other gases. Windows and one wall are built to give way readily in case of explosion.

Proposals for a second and a third phase of updating the physical plant were shown the Congressional delegation. The second phase consists of modernizing the main building, incorporating a structural laboratory for research on whole buildings. The third involves updated facilities for research in solid wood products.

The Congressional delegation was also acquainted with other phases of FPL research, notably its current work on low-cost housing, reclamation of municipal paper wastes for reuse of the fiber, experiments in sawdustless lumber cutting, and the development of nonleaching fire retardants for shingles and other wood parts of houses.

FPL's low-cost housing research won wide recognition during the year. L. O. Anderson, architect-engineer who designed five houses and wrote a building manual to aid in the training of workmen, was given the U.S. Department of Agriculture's Superior Service Award by Secretary Clifford M. Hardin.

Among other outstanding developments of the year was the acquisition, from the Yale University School of Forestry, of the Samuel James Record Wood Collection, the largest of its kind in the world. The collection is described elsewhere in this report.

Environment-Related Research

In spite of the protestations of nature lovers and protectionists, the annual harvest and use of 12½ billion cubic feet of wood is accomplished with far less disruption and pollution of the environment than is that of any other major industrial resource. Add to this the facts that wood is a renewable resource and that nature can recycle it back into the "life cycle" without permanently harming the environment, and it appears that wood may truly be the ideal raw material for a crowded world of tomorrow. The challenges that confront research are—more complete utilization, elimination of polluting side effects, recycling of used products, and ultimate disposal without lasting harm.

Some parameters of the basic problem are apparent in the 2 billion cubic feet of potentially usable logging residue left in the woods, the 2.4 billion cubic feet discarded at mills and factories, and the 50-plus million tons of paper and paper-board products that pile up in supermarkets, warehouses, and household trash cans. Others, dimensionless but insistently obvious, include the smoke of burning logging slash and sawmill burners and the sulfurous fumes of chemical pulpmills.

FPL's environment-related research has the dual objective of reducing the pollutive effects of forest products residuals and, by converting them to useful products, contributing to the conservation of our timber resources. This section covers mainly research on ways of reclaiming wood fiber in household trash and reducing air and stream pollution that results from pulping of wood, together with developments in research on wood residue for stock-feed. Research dealing with utilization possibilities of residues resulting from timber harvesting and most mill processing is covered elsewhere in this report under the section entitled "Timber Supply and Utilization."

Reclaiming Consumer Discards

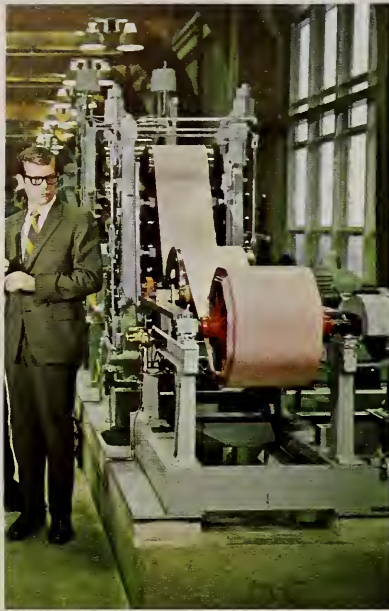
Of the 53.5 million tons of paper and paper-board products manufactured in 1969, only a minor portion was recaptured for reuse. As much as 40

million tons were destroyed after a single use—burned or consigned to rot in municipal dumps. The cost of collecting and disposing of trash is itself a steadily mounting item in municipal budgets. Pollution of land, air and waters adds inestimably to these costs. And the loss of potentially reusable material constitutes an intolerable dissipation of natural resources.

FPL research is aiming directly at the heart of the reclamation problem. Its target for the 1970's is to demonstrate the technological feasibility of recycling back into the production process up to one-half the fiber now lost. Through a fortunate combination of circumstances, agreement was reached with the City of Madison to obtain all the raw material needed for reclamation research in a form much more usable than conventional trash. This became possible because the City had instituted a sanitary land-fill operation based on a hammermilling process of reducing trash to small bits and pieces. The hammermilled material proved much more suitable for segregation of heavy and light materials—paper from metals, for example—than unprocessed trash. Wood-fiber products comprise some 55 percent of the hammermilled trash by weight. The experimental processing begins with existing machines that appear suitable for segregating heavy from light materials. Several types of blower machines were tried in experiments to gage relative efficiency.

FPL experimentation also includes a three-stage cleaning process for the light material segregated by the blower systems, and utilization research with the reclaimed fiber. Several grades of fibers are recovered by wet processing, which includes pulping and screening the wood-fiber materials, passing them through a flotation tank, and centrifuging them. At each step non-fiber materials such as ground glass and plastics are removed.

The heterogeneous character of the fiber obtained is due to the mixture of different types of paper made of various kinds of wood pulp, from newsprint groundwood to sulfite bond. Neverthe-



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Recycling... The Treasure in Our Trash

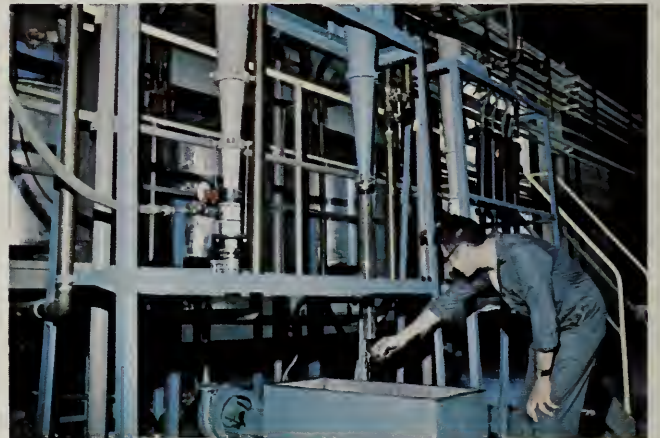
FPL research explores techniques for reclaiming wood fiber.

1. Municipal trash of Madison, Wis., is collected here for hammermilling into sanitary landfill material.
2. Hammermilled paper is fed into FPL pulper.
3. Dirt, other contaminants are screened from pulp.
4. Pulp is further purified in centrifuging devices.
5. High-quality printing paper is made from best fiber.



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less, reclaimed fiber of best quality has been shown to be suitable for printing-type papers. Less pure grades will be consigned to experimental fiber building boards of various types or processed to make roughage and carbohydrate for livestock feeding experiments.

The entire reclamation process is based on existing technology, and is regarded as equivalent in an economic sense to the processing necessary to harvest trees and convert them to unbleached pulp. Beating, bleaching, and other refining processes used on virgin pulp can be readily adapted to refine reclaimed wood fiber also, it is believed.

While the economics of the recycling process appears favorable when equated against the costs involved in producing pulp from trees, vastly greater social and economic benefits result from the alleviation of pollution and other disposal problems. Still another beneficial function is, of course, the replenishment of resources that results and the lessening of the ever-mounting drain on the forest resource.

Air, Stream Pollution Abatement

FPL research directed toward abatement of pollution caused by residuals of pulping and papermaking has in recent years yielded processing and recovery developments now ready for industrial use. Currently, basic investigations of entirely new process approaches are under way that hold promise of freeing the industry from the causative agents.

Research achievements that now appear ready for industrial application include two process modifications of neutral sulfite semichemical (NSSC) pulping and an alkaline chemical recovery system that substantially reduces air pollution and simultaneously contributes to process economy. FPL scientists consult with technical personnel of industrial firms interested in them.

One modification designed to alleviate stream pollution by spent liquors of the NSSC process involves a direct smelt oxidation technique much simpler and less costly than existing sulfite recovery methods. The other makes possible recovery and reuse of pulping chemical by substituting a magnesium for the conventional soda base.

The alkaline chemical recovery method was devised for a new polysulfide pulping process that yields 20 percent more pulp than conventional kraft pulping. It involves a combustion method that can substantially reduce air pollution, which is a major drawback of kraft pulping. This is done by (1) eliminating causticizing, mud handling, and lime kiln equipment and (2) operating the oxidation furnace separately from the reduction furnace to achieve a simple and unhindered combustion of a large volume of dilute pollutive gases.

The principal causative agent of air pollution in the kraft process is the sulfur used in the cook-

ing liquor. Only by eliminating all sulfur compounds can an odor-free atmosphere be assured in the vicinity of pulp mills. At FPL, as well as elsewhere, such processes are being sought. One promising line of research involves oxygen delignification. A commercial process appears at least a decade away. The target would be a pulp comparable in all respects to kraft and produced by a process equivalent to or exceeding kraft in yield and efficiency.

Another approach being researched is specific removal of lignin with liquid ammonia, using oxidizing agents. A suggested use for the lignin obtained is as agricultural fertilizer. It would prevent leaching of nitrogen from soil that occurs with conventional fertilizers.

The dissolved and suspended solids that pollute water principally by consuming oxygen as they degenerate consist mainly of lignin and some cellulosic material. Such solids are byproducts of all pulping and of pulp bleaching and papermaking as well. Effluents containing them are first given a primary treatment whereby the settleable solids are removed; this is followed by a secondary treatment consisting of some form of biodegradation. Dewatering and disposal of fines and hydrocolloid-type sludges from such disposal systems, however, remains a problem. These residues also contain inorganic salts that must be specially treated to destroy their nutritional value to algae.

FPL research is directed toward developing methods for studying surface phenomena involved in the dewatering difficulties associated with the cellulosic hydrocolloids in effluents and sludges, and finding means of utilizing them for papermaking.

Wood Residues for Stockfeed

Red oak sawdust has good possibilities of becoming a source of carbohydrate for livestock as a result of experiments with various treatments aimed at improving its digestibility. One treatment stood out in digestibility trials with rumen fluid obtained from cattle. Digestion levels of 50 to 55 percent—comparable to hay—were attained in treatment with gaseous sulfur dioxide at elevated temperatures and pressures.

The experiments are part of research to gain reliable information on the possibilities of utilizing sawdust as a feed supplement. Its value as a roughage to stimulate saliva flow in ruminants on high-concentrate feed rations has been quite well established in related work conducted in cooperation with the Tennessee Valley Authority, Penn State and Auburn Universities, and the University of Wisconsin, and covered in previous Annual Reports.

Other treatments improved digestibility of some species, notably aspen. Only sulfur dioxide gas



Aspen sawdust pours from a digester after having been treated with anhydrous ammonia to improve digestibility for livestock. Treatment swells wood and attacks acetyl and uronic acid groups.

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was effective with oak, however. Other treatments included electron radiation, found much too high in cost; vibratory ball milling, commercial equipment for which is not suitable; and swelling in anhydrous ammonia or dilute sodium hydroxide solutions. The latter two are effective with some species but not others, notably the target species, oak.

Some digestibility experiments were also conducted on fiber residues of pulping processes. Roughly 80 pounds of waste fiber are generated for each ton of pulp produced, ranging from totally unmodified groundwood fines to fully pulped and bleached Centricleaner fines that are essentially pure cellulose. All but the groundwood fines appear to have feed potential.

A complex system of weights was used to exert forces simulating wind loads on this hyperbolic paraboloid roof in a study of its design characteristics.



Housing Research

FPL housing research during 1969 was punctuated by the Nation's mounting needs for more housing, Government actions to stimulate new and more sophisticated ways of producing that housing, and the destruction caused by one of the worst hurricanes ever to strike the continental United States. Together these developments plunged its scientists into deeper and more direct involvement with urgent national problems than ever before in time of peace.

A single product of FPL housing research dramatically symbolized that involvement. Five sets of plans and specifications for houses for low-income groups were prepared especially for use in rural areas and made available for distribution with only limited publicity. Within a matter of months, nearly 5,000 sets had been mailed out, and continuing requests made it necessary to shift distribution to the Superintendent of Documents, Government Printing Office, Washington, D.C. Inclusion of information about the plans in a Forest Service pamphlet entitled "Designs for Low-Cost Wood Homes" stimulated many more thousands of inquiries. Copies of this pamphlet are obtainable from FPL free on request.

During the year the plans also became available at many of the 1,500 offices of the Farmers' Home Administration in all parts of the United States, and through the Agricultural Extension Service. While it is impossible to ascertain how many homes were actually constructed during the year with these plans and specifications, a number were built with Farmers Home Administration financing in various parts of rural Wisconsin. In some cases loans were made with interest subsidies authorized by Congress in the 1968 Housing and Urban Development Act.

According to reliable reports, basic construction costs for the houses were reduced to almost one-half the cost of traditional houses of comparable size. Not included were costs of land and of utilities to the lot line.

Construction is conventional, all minimum

property requirements of the Federal Housing Administration are met, and the houses are structurally sound, durable, easy to maintain, and comfortable. The lowered cost is achieved through simplified design, elimination of site preparation through the use of treated wood foundation posts, single-thickness exterior sheathing-siding and flooring, a minimum of trim, and compact arrangement of plumbing, heating, and electrical utilities. The simplified construction facilitates the training of local labor, and use of conventional building materials benefits local business and industry.

To aid in the training of workmen and do-it-yourselfers lacking the necessary skills and technology, a manual was published under the title, "Low-Cost Wood Homes for Rural America—Construction Manual." Printed as Agriculture Handbook No. 364, it is available from the Superintendent of Documents, Washington, D.C., for \$1 a copy.

While the stress has been on economy in design and construction of these houses, they provide comfortable and complete living facilities and represent immense improvement for much existing rural housing, as described in a report of a President's National Advisory Commission on Rural Poverty in 1967. This report stated:

"Decent housing is an urgent need of the rural poor. They live in dilapidated, drafty, ramshackle houses that are cold and wet in winter, leaky and steaming hot in the summer. Running water, inside toilets, and screened windows are the exception rather than the rule. . . .

"Census data shows these conditions are all too typical:

"In 1960, 27 percent of occupied rural housing was classified as substandard—deteriorating or dilapidated—compared with 14 percent for urban areas.

"Of the 9.2 million substandard occupied housing units in the Nation, 3.9 million were in rural areas.

"More than a million rural homes are dilapi-

Housing for Low-Income Rural Families

FPL-planned for small or large families, designs emphasize economy, simplicity.

1. Two-bedroom plan FS-FPL-3 was used without carport to build this house near Wisconsin Rapids, Wis.
2. Five-bedroom plan FS-FPL-2 provides 1,404 square feet of living space.

3. Single-thickness plywood outer wall covering economizes on material, site labor. Floors are also single thickness plywood.
4. Standard preassembled double-hung windows speed closing-in.
5. Economical pine trim complements dry-wall interiors.



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dated—structurally unsafe for human occupancy. Many of these homes are beyond repair.”

HUD Cooperation

In response to the Department of Housing and Urban Development program called Operation Breakthrough, conceived to find better and faster ways of building housing, some 200 industrial concerns submitted proposals for housing systems to be considered for evaluation in prototype construction. A number of these involved wood, and some incorporated structural principles evolved from FPL research—notably stressed-skin and sandwich concepts. Because of FPL’s broad experience in wood housing research, HUD called upon its housing specialists to assist in preliminary screening of the proposals for merit.

Several FPL staff members spent considerable periods in Washington, D.C., in the late months of the year studying proposals that involved wood construction and making recommendations. Proposals included single-family detached houses, single-family attached buildings such as row-houses and garden apartments, and both low-rise and high-rise apartment buildings.

The screening was preliminary to a final selection of 22 proposals by HUD for commission of detailed plans and specifications. These, it was expected, would be further evaluated in 1970, and a number of prototype constructions would be built in various parts of the United States. Evaluation

criteria would be structural adequacy, safety, and general livability of the designs.

Rehabilitation

Obsolescent and deteriorated housing often is structurally sound and can be repaired and remodeled to bring it up to acceptable residential standards at reasonable costs. Often the greatest obstacle to such rehabilitation is the lack of know-how and trained labor.

To overcome this obstacle, FPL housing specialists are assembling information from past research and from builders experienced in commercial rehabilitation of wood-frame houses and multifamily dwellings. This information will be prepared in manual form for the guidance and training of contractors, workmen, and owners of such dwellings who may want to do the work themselves.

Hurricane Camille

The devastation wrought along the Gulf Coast of Mississippi and Louisiana by the unprecedented violence of Hurricane Camille in August 1969 provided a rare opportunity to study the capacity of various kinds of construction to resist its forces.

A few days after the storm struck August 17, an FPL specialist visited the scene with an architect of the Southeastern Forest Experiment Station, Athens, Ga. Some of their conclusions, as published in a subsequent report:

1. Shoreline structures pounded by 20-foot

Gable roofs (right) were damaged more severely than hip roofs of houses by Hurricane Camille.



waves were heavily damaged regardless of how well they were built. It was apparent, however, that structures sufficiently elevated on wood piles have a much better survival chance than those on conventional foundations when hit by waves.

2. Winds up to 190 miles an hour appeared to damage hip-roofed houses less than those with gable roofs.

3. Some of the worst wind damage inflicted on wood-frame houses was attributable to faulty nailing of roof framing to walls.

4. Roofs framed with rafters should be reinforced with collar beams—boards that connect the rafters 2 or 3 feet below the ridge.

5. Roof trusses help buildings resist hurricane winds even when masonry walls collapse.

6. Mobile homes should be fastened to wood post foundations or otherwise tied down to prevent high winds from overturning them.

"Well-built conventional wood-frame construction," the report concludes, "performed exceptionally well in Hurricane Camille except when subjected to extreme wave action. Wood-frame houses, in particular, exhibited remarkable resistance to the high winds. Apparently, conventional construction whose components are well attached to each other is adequate to resist the wind forces in hurricane zones."

Wood-Fiber Sound Insulation

Wood-fiber building materials can be designed to provide excellent suppression of sounds within a home or other building, experiments showed. Such sounds include the familiar noises given off by washing machines, vacuum cleaners, dishwashers, radios, TVs and stereo phonographs, toilets and slamming doors, as well as humans and pets.

Woodbase building materials can be designed to muffle such sounds generated within a building, where the problem consists of suppression of the sound waves. Experiments showed that wood-base materials differ widely in their sound-damping capability.

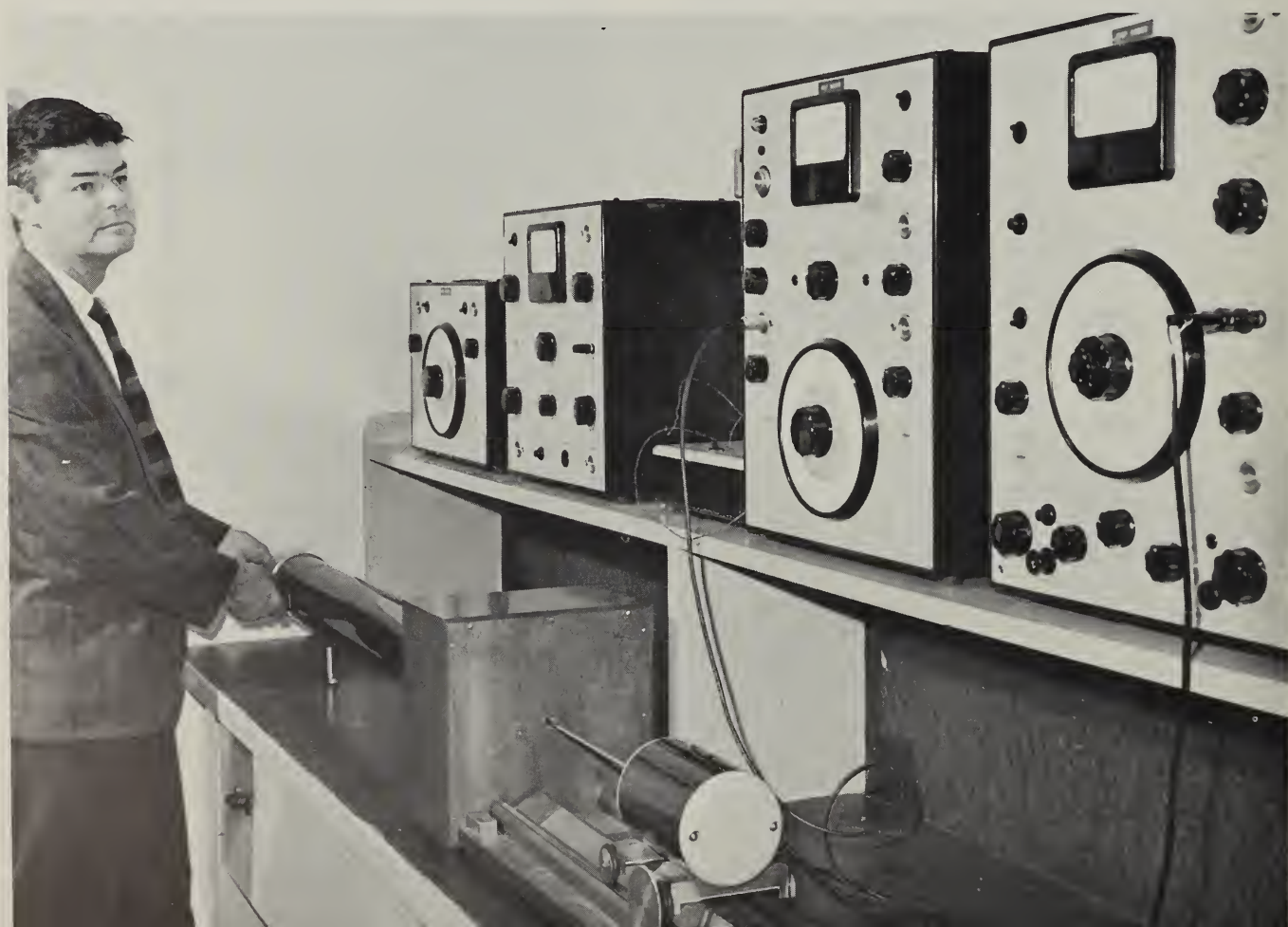
The experiments were carried out with a gun-like contrivance called an impedance tube. It shoots sound of a single frequency from a loudspeaker against a sample of material. How much of that sound is absorbed by the material is measured in terms of what happens to the sound waves as the reflected one clashes with the original one.

Much depends also on the pitch of the sound. Low-pitched sounds are less readily absorbed than high-pitched sounds. The experiments covered a range of sounds from 125 cycles per second—a low tone—to 4,000, a high whistle.

Sound absorption involves changing sound energy into some other form, usually heat, as the

Impedance tube apparatus used by electronics technologist W. D. Godshall to evaluate sound insulating value of wood-fiber building products.

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sound passes through a material or strikes the surface. Porous materials are best because they provide frictional drag, which generates heat as the sound waves pass through them. The proportion of sound energy so dissipated is termed the sound absorption coefficient. Absorption coefficients were ascertained for various wood-fiber acoustical tiles insulation board tiles, plywood, several types of particleboard, perforated hardboards, and 1-inch and 2-inch wood-fiber felt.

An especially effective sound-damping combination, the experiments revealed, is perforated hardboard with a backing of wood-fiber felt. With a 1-inch backing, the material muffles high-pitched sounds very well. Thicker backings are also effective against lower pitched sounds.

UV Absorbing Wood Finish

A wood treatment found effective in absorbing ultraviolet rays and being tried experimentally as a substrate for clear natural finishes to prolong their service life is also undergoing evaluation as a wood finish in itself. Its low cost, and the fact that it can be sprayed on wood in a single application, promise economies for low-cost housing, farm buildings, and other structures. Estimated service life is 4 to 6 years, and renewal appears to present no unusual problems. It is being service-tested on a number of buildings, including a University of Wisconsin cattle shelter.

Principle ingredient of the formulation is ammoniacal copper chromate. This is classified as a pesticide or "economic poison" subjected to the Federal Insecticide, Fungicide, and Rodenticide Act. The reader's attention is directed to a statement regarding use and registry of pesticides on the inside back cover of this report.

Related research on wood finishes is discussed elsewhere in the section of this Annual Report headed "Protection of Wood in Use."

Nailed Joint Design

Applying a century-old theory of beams on elastic foundations, FPL engineers have developed a simplified design formula for determining safe loads that is applicable to most commonly used nailed wood joints. The expression, for a simple two-piece joint loaded laterally parallel to the

grain, has been verified experimentally.

The expression is based on a species parameter, the elastic bearing constant, that varies with the specific gravity of wood. It is therefore applicable to all wood species as well as to smooth round nails of any size when the properties of the nail material are known. It can be used to calculate allowable load for a given joint slip up to proportional limit, or slip for a given load. Thus the designer can establish the slope of the load-slip curve to proportional limit as a guide for safe, efficient design of joints made of a particular kind of wood and nail. The expression:

$$P = 0.1667 E^{1/4} k_o^{3/4} d^{7/4} \delta$$

Structural Rigidity of Pole Building

Even roof shingles contributed measurably to the rigidity of a pole building erected for storage use in the Laboratory's Building Research Park, experiments with loads equivalent to three wind speeds showed during tests at various stages of construction.

The loadings began on the poles when first set in place and were repeated when connecting headers were installed, when trusses were raised in place, when roof sheathing, soffit, trim, and gable ends were installed, and when shingles were laid. The tests with roof sheathing in place were made twice, with frozen and unfrozen ground.

Rigidity was determined by measuring the deflection of poles near the top when the load was applied by attaching a cable and pulling inward with a winch.

Pole deflection averaged about a quarter inch less at a 30-mile wind load when headers were installed, decreasing from 0.97 to 0.72 inch. The largest single improvement occurred when the trusses were attached; deflection dropped from 1.54 to 0.88 inch with a 42-mile wind load. Frozen ground contributed markedly also to rigidity, preventing the poles from packing the ground as they were pulled.

It is planned to repeat these experiments at intervals during the life of the structure. Comparable data are not available for conventional light-frame house construction.

Timber Supply and Utilization

A looming timber shortage, forecast by economists to arrive by 1980, raised fresh concern among researchers during the past year about existing utilization practices—and especially the residues left. These range from broken logs, branches, and cull discarded in the woods during harvesting to the sawdust and shavings, pulp fiber, and other processing losses that cumulatively account for some 70 percent of the substance in every tree cut.

Residue has always presented a challenge to FPL scientists, and many ways have been found to reduce it or use it—from more efficient sawing and seasoning to higher yield pulping processes and new products made in part or entirely of residue. Nevertheless, much is still lost along the way from forest to consumer.

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A hard, analytical look at the nature and volume of this waste has revealed intriguing possibilities. As much as 2 billion cubic feet is left annually in the woods in the form of cull and broken logs, tops, branches and roots. Some 1.7 billion cubic feet, including bark, are discarded at sawmills, veneer mills, pulp mills, and similar primary manufacturing plants. Residues of secondary manufacturing plants—among them drying installations, millwork and furniture plants—total some 700 million cubic feet a year.

Altogether, these losses amount to 4.4 billion cubic feet of wood and wood substance. Certainly they constitute a major challenge to research and development! And a major source of raw material to offset the predicted timber shortage, even though there is an even more critical shortage of time in which to accomplish the necessary research and development. Up to 3.1 billion cubic feet could be utilized, it is estimated, through research that leads either to reduction of waste or to utilization of residues. Better engineering designs that utilize wood more efficiently in structures could, together with recycling of used fibers and wood debris, raise the total potential gains through improved utilization to 4.7 billion cubic feet.

Intelligent utilization of any resource is contingent upon a sound working knowledge of the character and properties of the resource. To get the necessary facts about timber residues, a committee on increased tree utilization was set up at FPL. This committee was also charged with responsibility

for conducting research on the production of wood products from residues, evaluation of the quality of the products, and relating the properties and characteristics of the residues to the quality of the products.

Information of this nature is essential to interest and guide industry in the utilization of residues.

Harvesting Residues

One starting material selected for this evaluation program was harvesting residues. An investigation was begun to compare the usefulness for fiber products of two categories of such residue. One consists of limbs, tops, and roots over 1 inch in diameter, the other of debris less than 1 inch in diameter, along with needles and leaves. Hardboards and paper pulps are to be made from various fractions of these residues—so that, for example, a certain pulp made of limb material can be compared for yield and quality with the same kind of pulp made of conventional pulpwood bolts. Bark tolerances for various products are to be evaluated, along with amounts of chemical needed to dissolve bark during pulping and similar factors that affect production economics.

This comprehensive survey, while well under way, is expected to continue for several years before the range of data contemplated becomes sufficiently broad for practical use.

Some related work has already given results that point out logical directions to take in developing needed information. For example, bleached kraft pulps of surprisingly good yield and quality were made from unbarked aspen shoots 1 and 3 years old. Yields were 35.1 percent of the dry wood weight for the year-old shoots and 40.3 percent for the 3-year-old shoots, compared with a yield of 55 percent for mature wood. Year-old shoots had 79 percent of the bursting strength of mature wood pulps, 91 percent of the tear, and 81 percent of the tensile strength.

The work suggested the need for further research to answer such questions as the stand age and density at which the greatest yield of most desirable fiber is obtained; the age at which the species approaches mature wood in pulp yield and quality; and amounts of chemical needed to dissolve the bark.



The swelled butts of these water tupelo trees are normally left in the woods when the tree is harvested. FPL experiments showed their suitability for paper manufacture.

Data dealing with these aspects of pulpwood production were obtained in 1968 from an experiment with Mississippi cottonwood trees 7 years old but already up to 40 feet tall and 10 inches in diameter. Pulp yields and papermaking quality were comparable to those from normal mature cottonwood.

Water tupelo, a tree of southern swamplands, develops a swelled butt log that is often left standing in the woods or cut off and left to rot. Kraft pulping experiments with such butt logs furnished by the Southern Forest Experiment Station revealed that exceptionally good greaseproof papers—those used to wrap butter and other oily products—can be made from the fiber. Good quality corrugating medium was also made from neutral sulfite semichemical pulps of this wood, which is of little value for lumber or veneer because it is too weak.

A somewhat earlier study related to this work had also shown that 8-year-old southern pines cut out in stand thinning operations can be pulped to make softer and more absorbent tissue papers than can be made from mature southern pine. Pulp of these juvenile trees was in fact comparable to that made from mature northern softwoods.

Processing Residues

Work along the same lines of fiber characterization and pulp quality assessment is contemplated on residues of processing plants. There has been a steady increase in the use of these residues for pulp chips, especially in the Pacific Northwest, where it is estimated that three-fourths of the 10.5

million tons of wood pulped comes from residues of sawmills, veneer mills, and the like. Most of that utilization has come about in the past 5 years.

The use of residues for pulpwood has created an auxiliary problem, especially in the Pacific Northwest. Enormous piles of chipped residue are stored outdoors, sometimes for extended periods. Economic losses during such storage can amount to \$10 million per year. FPL scientists are searching for ways to mitigate these losses, which are due primarily to chemical and biological action but also to spontaneous combustion.

A low-cost treatment now being tested consists of spraying chips with so-called "green liquor" obtained in normal chemical recovery systems from spent kraft pulping liquors. In laboratory-scale experiments the chemical, primarily sodium carbonate and sodium sulfide, greatly reduced weight loss due to decay fungi and helped keep interior pile temperatures down.

FPL research in wood chemistry ties in directly with residues of another kind—those discarded by pulp mills. Some of this work was originally carried out on solid wood residues. Economic conditions, however, have made it appear more immediately applicable to the waste streams of pulp mills.

For example, FPL research on furfural production from certain carbohydrates in wood has led to the production of this well-known industrial solvent and resin constituent from certain pulp mill spent liquor streams. A cooperative study of this type with a pulp manufacturer led to the firm's decision to build a furfural plant, which is now under construction.

FPL chemists envision the development of new pulping processes that make possible integrated production of pulp and various chemicals. For example, FPL research on molasses production by hydrolysis of wood pointed the way to large-scale production of this stockfeed concentrate by a hardboard manufacturer.

Foreign Woods

Despite its great forest wealth, the United States has for some time been a heavy importer of wood and wood products. In 1967 the round-wood equivalent of its imports over exports was 1.2 billion cubic feet. Timber products worth nearly \$2.1 billion were imported. As the predicted timber shortage materializes, imports can be expected to increase.

FPL research has been mainly devoted to establishing basic identification techniques and the properties and characteristics of foreign woods. This work has been under way on a small scale for many years, during which an extensive volume of data has been obtained. In recent years the work has been concentrated largely on Latin American woods. At a Conference on Tropical



1.

Collected Curiosities...

Among the 55,000 wood specimens in the Samuel James Record Memorial Collection are some rare curiosities:

1. This African "tree," *Wellwitschia bainesii*, grows mainly underground. (Photo courtesy South Africa Dept. of Forestry.) M 137 572
2. From some tropical Latin American forest came this monkeyladder vine, of the genus *Bauhinia*.
3. How some trees grow in the Amazon valley is shown by this cross section of the trunk of paddlewood, a species of *Aspidosperma*.
4. On the island of Martinique, French West Indies, native craftsmen long ago carved these house columns of tree fern, a species of *Alsophila*, being admired by FPL's wood identification leader, Dr. B. Francis Kukachka, and Secretary Judy Kent.



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Hardwoods in August 1969 at Syracuse University, Dr. B. F. Kukachka, in charge of FPL research on wood structure and identification, presented a paper summarizing data on tropical hardwoods of some 90 genera. This paper is to be published by FPL as Research Paper FPL 125.

Expanding imports of tropical hardwoods, especially from Latin America, are expected as a result of increasing shortages of domestic fine hardwoods. The three main sources of tropical species are the Amazon basin of South America and adjacent areas extending into Central America; equatorial West Africa; and the islands and peninsulas of Southeast Asia. Of these, the Amazon basin is perhaps the least exploited, but its timber includes an extraordinary variety of species.

From the standpoint of density, the majority of tropical species fall within the density range of our native commercial hardwoods. There are, however, a few important differences. Tropical hardwoods often have interlocked grain, which makes seasoning and machining more difficult. Some of them also contain silica, a gritty substance that wears machining tools rapidly and is never found in temperate-zone hardwoods.

Samuel James Record Collection

FPL's identification service to importers and others has been greatly assisted by the acquisition of the Samuel James Record Memorial Collection of wood and herbarium specimens from the Yale University School of Forestry. Included in the col-

lection are some 55,000 wood specimens representing more than 14,000 tree species in about 3,000 genera. Herbarium material consists of some 25,000 specimens of leaves, flowers, and fruits of different tree species.

The collection will be maintained intact. As it happens, the collection dovetails well with FPL's own collection of some 25,000 wood specimens, including more than 6,000 species in 1,820 genera. The Record collection consists largely of tropical woods, while FPL's has perhaps the world's best representation of North American species.

The late Dr. Record built the collection from a few hundred specimens available when he began teaching in 1910 to over 41,000 when he died in 1945. It helped establish the Yale School as a world center of information on tropical woods. On it Dr. Record and an associate, Robert W. Hess, in large part based their authoritative book, "Timbers of the New World," first published in 1943.

The collection will be available to qualified students and teachers for research and study. Included in the collection are Latin American woods from Argentina, Brazil, Colombia, Costa Rica, Bolivia, Cuba, Guyana, Surinam, and Panama. Specimens from the Orient include woods of Java, Malaya, Sumatra, India, Fiji, and New Guinea.

The Record collection is the largest of its kind in the world. Together with the FPL collection, it provides an unmatched variety of specimen material for identification, research, and study purposes.

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Protection of Wood in Use

Under some conditions of use, wood requires protection from natural enemies. Primarily, these are weather, fire, and biological organisms. A major area of FPL research, concerned with improving such protection, ranges from study of paints and other wood finishes to the pathology of decay, the entomology of wood-destroying insects, and the chemistry of combustion. The scope of this work is indicated by the facts that (1) 40 million home owners are concerned with painting and other maintenance; (2) decay and insects annually cause damage estimated at \$600 million; (3) and damage by residential fires is put at another \$600 million.

Wood Finishes

The role of paints in preserving the appearance of wood and protecting it from weather has long been known. FPL research that disclosed the deteriorating mechanisms of ultraviolet light, however, has made possible sound progress in the development of durable clear natural finishes. It was unmistakably demonstrated that UV rays passed through the clear UV-transparent finish and attacked the wood underneath. The need for a UV-absorbing type of wood treatment was recognized, and an effective absorber was found in copper chromate.



FPL Pathologist Joe Clark participated in a 1969 survey of totem poles remaining at old Indian villages along the Alaska coast. Poles were numbered and inspected for condition. These were photographed at Old Kasaan, an abandoned village on Prince of Wales Island. They date back to the turn of the century or before. The Indian carvers removed bark and easily decayed sapwood from the western redcedar logs before carving them. Totems memorialized Indian heroes.

In exposure tests, this absorber has greatly prolonged the service life of clear natural finishes, such as the UV-transparent methyl silicone. The success of this work has given rise to the expectation that natural clear finishes with a service life equal to that of conventional pigmented paints can be attained. The chromate is in effect a pigment that functions in much the same manner as conventional pigments in protecting the paint.

Work is now under way on the incorporation of other pigments into wood that also inhibit fungal growth. By precipitating these into the surface layers of the wood along with a UV absorber, it is hoped to provide protection from fungi that attack the clear finishes. This work is being done in cooperation with the National Forest Products Association and the National Paint, Varnish, and Lacquer Association.

Protection From Fungi

FPL research to find better ways of treating wood against fungi that cause decay, mold, and stains is proceeding along two lines. One involves conventional toxic treatments and the other, the new FPL-originated nontoxic process that renders wood unsuitable for fungal growth by removing an essential trace element, such as thiamine (vitamin B).

Pressure-type preservative treatments have long been in wide use to protect wood under service conditions that present high decay hazards, as when in contact with the ground or water. Some woods, however, are hard to treat adequately by such processes. Deep penetration is all but impossible. For these, a more effective treating process is FPL's double-diffusion method, by which two water-soluble chemicals are successively diffused into the wood and react with each other to form an insoluble, and therefore unleachable, compound. The treatment's effectiveness with species such as Douglas-fir, which are difficult to treat by pressure, has been greatly improved in experiments with a heated preservation solution. Incising of the green wood also promoted diffusion of the chemicals into the wood.

Another persistent problem for which a solution appears near involves the ineffectiveness of creosote in apparently well-treated marine piling at some warm water harbor installations. Creosote, a well-established toxic preservative widely used for protection from marine borer attack, can under some conditions lose its effectiveness in salt water before a satisfactory service life is reached. Experiments indicate that treatment first with another preservative, such as copper arsenate, followed by creosote, is highly effective. Cooperative work on this treatment is under way with the Naval Facilities Engineering Command, Department of the Navy.

Thiamine depletion continues highly promising as a nontoxic treatment for wood in exposure tests under the warm, humid, decay-fostering conditions of the Gulf Coast at the Forest Service's Harrison Experimental Forest near Saucier, Miss. This FPL process appears especially timely in view of increasing public concern about the environmental pollution hazard involved in use of pesticides (see statement on inside back cover of this Annual Report). The treatment so far looks suitable only under service conditions out of contact with the ground, hence cannot be regarded as a substitute for toxic preservatives under more rigorous service conditions. Its low cost, coupled with the fact that it leaves the wood clean, odorless, and paintable, appears to make it especially suitable for protection of wood used in housing and other structures above ground.

The economics of dethiaminization appears fa-

avorable. The ammonia gas treatment can be administered during kiln drying. Cost is estimated at about \$1 per 1,000 board feet of lumber.

Preservative-Treated Stringer Patent

Glued laminated beams, utility poles, and other structural members with greatly improved decay resistance even though made mainly of woods hard to treat with preservatives are covered in a United States patent issued May 20, 1969, to Joe W. Clark, FPL pathologist. The patent, No. 3,445,325, has been assigned by the inventor for licensing by the Secretary of Agriculture.

Dr. Clark conceived the idea covered by the patent during research on wooden bridges in National Forests of the South and West. He found that stringers which support the bridge floors frequently develop decay in their top surfaces.

Clark's patent proposes that the top three laminations of laminated bridge stringers be made of wood that is easy to treat. These laminations would be pretreated and glued to untreated laminations, which could be woods that are hard to treat. The finished beam would be given a final pressure treatment for overall protection. Another version of Clark's invention deals with solid or laminated poles, posts, and other structural parts to be used in contact with the ground. These would be covered on all four sides with plies of easily treated wood.

Protection from Termites

As a termite suppressant and possible exterminator, FPL's attractant-insecticide treatment has



Study of the life cycle of termites is facilitated by staining in various colors the naturally whitish aspen sawdust on which they feed.

shown unique advantages. Its potential, like that of dethiaminization, is enhanced by current concern over environmental pollution, because it involves only very small amounts of insecticide as contrasted with the volumes required for conventional soil-poisoning treatments around houses—on the order of 12 grams versus 200 pounds per acre. A low-cost, do-it-yourself package appears commercially feasible.

The treatment consists of setting small treated wood stakes about 5 feet apart outside a house or other structure to be protected. The attractant lures termites within a radius of 3 feet underground from the treated stakes. At one test site, termite population estimates indicated a reduction

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Gas jets will flame against this door for an hour in a standard test of its fire resistance.



of 70 percent a year after the treated stakes were installed.

Protection from Fire

Effective new fire retardant treatments for wood shingles with high resistance to leaching, long a drawback of fire-retardant chemicals, appear also to have good potential for treatment of lumber, plywood, and wood-base panel products used in housing.

One such treatment was used to gain a 1-hour "noncombustible" fire rating for an insulated wall assembly consisting of 2 by 4 studs and plywood facings. The construction met temperature requirements of the E119 test of the American Society for Testing and Materials, principally that there be not more than a 250°F. rise in tempera-

ture within 1 hour on the side of the panel not exposed to gas jet flames. The work was done in cooperation with the American Plywood Association and the manufacturer of the fire retardant.

A long-term evaluation of a number of fire retardants for wood shingles has shown that several appear suitably leach resistant to assure long service life. Several firms are engaged in commercial development of fire retardants for the purpose.

Another parameter needed to predict the fire endurance of wood assemblies is the strength characteristics of wood at elevated temperatures. Data on tensile and compressive strength are being obtained for Douglas-fir at temperatures up to 550°F. Results may make possible the prediction of the fire endurance of wood columns, beams, and other structural components.

Efficiency in Processing and Use

More complete utilization of available wood supplies depends to a great extent on more efficient conversion of the raw material brought out of the woods to mills and factories. As noted in the section of this report on "The Timber Supply and Utilization," the residues and processing losses that occur in primary and secondary manufacturing industries afford extensive opportunities for more complete utilization. Greater efficiency will also contribute to extension of the timber resource and minimize pollution. Reduction of residue and utilization of that which cannot be avoided comprise a major area of FPL research.

Computer Grading of Hardwood Lumber

Automation and the computer have taken over a large role in bringing greater efficiency to industry in general—including many competitors of forest products manufacturers. It is but logical, therefore, that FPL research should be deeply committed to the development of these invaluable tools for greater efficiency in production and use of wood products.

The use of computers to automate decision making in lumber manufacture came materially closer in 1969 with the successful development by FPL technologists of a computer program to grade hardwood lumber. In one test run, descriptive "inputs" of 153 boards were correctly graded in 40.15 seconds. This is far faster than human graders can do the job.

The breakthrough is a vital step in research aimed at computer automation of the decision making in sawmilling—how to break down logs, edge and trim flitches for highest grade yields, and the like. In related research, work is proceeding on lumber scanning devices that can sense and locate defects that affect the grade of the board. Ultimately, it is expected that scanning devices will feed computers the information necessary to enable them to make the decisions that control the sawing of logs and flitches.

Not only are computers expected to do the work faster; the full quality potential of each flitch or board should be realized. Value gains averaging \$13.50 a thousand board feet of hardwood lumber



This University of Wisconsin computer was used to test a program developed for grading hardwood boards by the rules of the National Hardwood Lumber Association.

are estimated; the system should cost less than half that.

As now envisioned, however, the system will not replace human lumber graders and inspectors. Requirements such as color, percentages of sapwood and heartwood, and special agreements between buyer and seller will continue to require visual grading.

Hardwoods were chosen for the initial work in the field of computer decision making because the generally mathematical nature of hardwood grading rules makes them adaptable to computer programming.

A mathematical description of the board and its defects is fed to the computer. This information is obtained by graphically locating defects according to a horizontal and a vertical scale divided into quarter-inch units along the length and width of each board. A given knot is thus located so many quarter inches from the lower left corner of the board. Its size is similarly designated by lower left and upper right corners of a rectangle enclosing it. Some irregular defects, notably wane and splits, are described by a series of such rectangles.

The grading system was devised to duplicate the mental process a lumber grader uses in analyzing each piece and reaching a decision as to optimum placement and sizes of cuttings it will yield.

The standard hardwood grades were also interpreted mathematically, and this information was fed to the computer as the basis for its decisions regarding the proper grade of each board.

In related research on scanning devices to "read" defect sizes and locations and transmit sig-



Experiments with different ways of cutting lodgepole pine logs into 2 by 4s showed how commercial sawmilling can be improved.

M 136 512

nals to computers, an instrument is used that shoots pulses of sound through flitches. Variations in the speed with which a pulse penetrates the flitch indicate the presence and location of certain defects. These signal-speed variations, further interpreted by the computer, constitute the mathematical descriptions which, it is hoped, can be used as computer inputs for decisions as to how to edge, trim, crosscut, and rip flitches to get maximum grade and scale of hardwood lumber.

Sawing Warp-Free Studs

Either of two sawing methods can produce from lodgepole pine logs two-by-fours that warp less than those cut by conventional sawing. One, called the Scragg method, is also in commercial use; the other is an FPL modification of the Scragg that does an even better job.

Large volumes of lodgepole pine are cut for two-by-four studs, which are shipped to many parts of the country to frame walls of houses and other buildings. The species has a reputation for greater than average warping. A medium-size tree, lodgepole pine grows from the Colorado Rockies to the eastern slopes of the Cascade Mountains in Washington. Some 52 billion board feet of sawtimber were estimated to be available in 1963, with large stands in Idaho, Montana, and Wyoming. Logs seldom are more than 14 inches in diameter; average size is probably about 8 inches.

In a conventional sawmill, a single headsaw cuts a log into 4-inch cants that are then ripped into 2 by 4s, usually by gangsaws. In a Scragg mill



Sawmill specialist Frederick B. Malcolm studies cutting action of new Steptooth design for sawteeth. M 133 382

the log passes between successive pairs of saws that remove 2-inch flitches and leave a 4-inch cant from about the geometric center of the log; flitches and cant are then ripped into 2 by 4s by gangsaws, generally parallel to the pith.

The FPL-improved Scragg method cuts 2-inch flitches and 4-inch cants the same way. Flitches big enough for 2 or more studs are then ripped parallel to the bark edges. Cants are similarly ripped parallel to the bark, leaving a center wedge containing weak, high-warp pith wood and yielding straighter-grained studs.

Results of the experiments yielded the following recommendations:

1. If crook—a form of warp that causes studs to curve edgewise—is a major problem, consider using the FPL-improved Scragg method and saw only upper logs into studs. Butt logs—the first 8-foot log above the stump—could be better used for lumber of wider dimensions, which has more inherent resistance to crook.

2. If twist is a major form of warp in lodgepole pine grown in a certain area, it can be reduced by increasing the percentage of butt logs and by increasing the average diameter of the log mix.

3. It is probably worth the small additional cost of handling to orient all logs so that the long radius is parallel to the plane of sawing before sawing them into cants and flitches.

Cooperating in selection of the 700 logs at a stud mill in West Yellowstone, Mont., were personnel of the Intermountain Forest and Range Experiment Station of the Forest Service, headquartered in Ogden, Utah.

Other Sawmilling Research

A sawmilling study is in progress on hard ma-

ple logs sawn for factory lumber. This product is used by furniture and cabinet makers on the basis of the number of usable cuttings obtainable from each piece in desired sizes; generally these cuttings are sawn from between knots and other defects. A survey has shown that up to 54 percent of the log volume becomes waste, half of it due to warp. Sawing methods are being experimented with to reduce this waste.

Automated Dry Kiln

Automated controls have potential to greatly increase the capacity of conventional dry kilns for hardwood lumber by slashing drying time, and also cut costs and losses from warp, checks, splits, and similar damage by maintaining close control over drying conditions in the kiln.

Such automated controls were installed on an experimental kiln. Estimated cost of equipping a conventional kiln is about \$5,000. Operation is simple enough that the kiln operator need not be an electronics expert.

The controls keep constant vigil over drying conditions in the kiln and the changing moisture content of the lumber as drying progresses. Actual conditions are balanced against desired temperature and humidity schedules for which the controlling mechanism is programmed. Steadily changing schedules are thus suitable for use instead of conventional step schedules designed for periodic manual control by operators. Steam valves are adjusted and air vents opened and shut round the clock. As the wood dries and loses weight, a load cell signals the changes to a device programmed with the right kiln conditions for lumber at any moisture content.

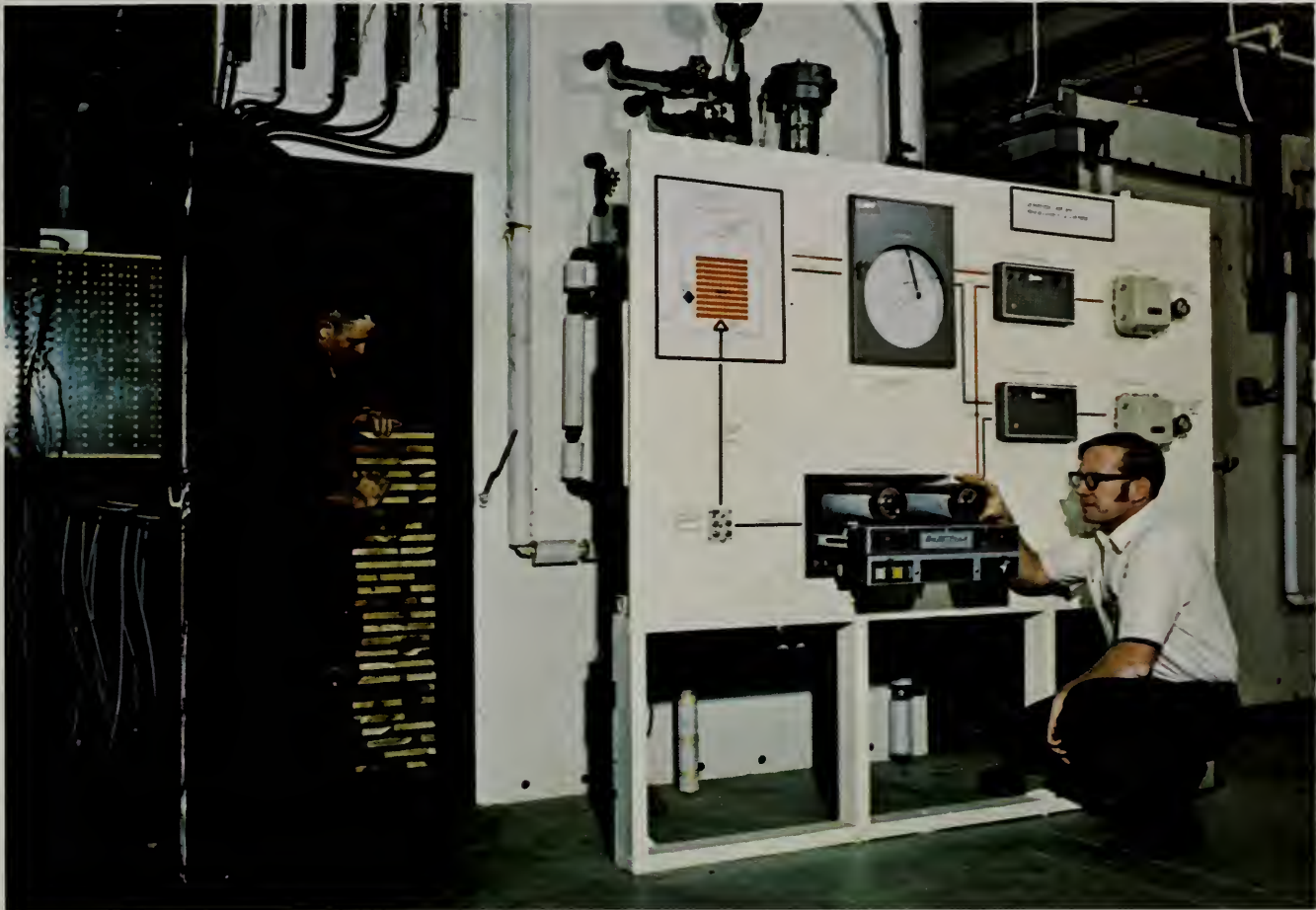
The lumber used in the initial experiment had been presurfaced as a further aid to fast drying—another advance resulting from recent FPL wood drying research.

The oak boards were brought from a moisture content of about 70 percent to about 7 percent in 14¼ days. Drying time for the usual commercial charge ranges from 20 to 28 days. Red oak was tried for the initial run precisely because it is difficult to dry without costly degrade, and because of the availability of the new step schedule based on the drying stress information.

Degrade losses with red oak commercially kiln dried are conservatively estimated at 5 to 7 percent. Costs of a commercial manually operated kiln are reported to run \$30 to \$50 a thousand board feet for green oak 1-inch lumber.

Improved Hardboard Stability

Higher press temperatures than those usually used commercially can substantially improve the dimensional stability of hardboard, while at the



Automated controls of experimental kiln are mounted on this panel that charts their functions. Eugene Wengert, technologist in charge of the research, adjusts programmer that computes necessary kiln conditions at any stage of dryness of the lumber charge.

M 137 236-5

same time markedly shortening press time and increasing press capacity.

Commercially dry-formed aspen mats taken from an assembly line with wax size and phenolic resin binder already incorporated were pressed in an oil-heated FPL press at five temperatures from 385° to 500° F. After being conditioned to equilibrium at 30 percent relative humidity, the boards were exposed for 30 days to either 65, 80, or 90 percent relative humidity or soaked in water.

Biggest stepwise gains in dimensional stability occurred between press temperatures of 385° and 425° F. The higher the pressing temperature, the better the stability. Pressing time was 70 percent shorter at 500° F. than at 375° F.—from 120 to 30 seconds.

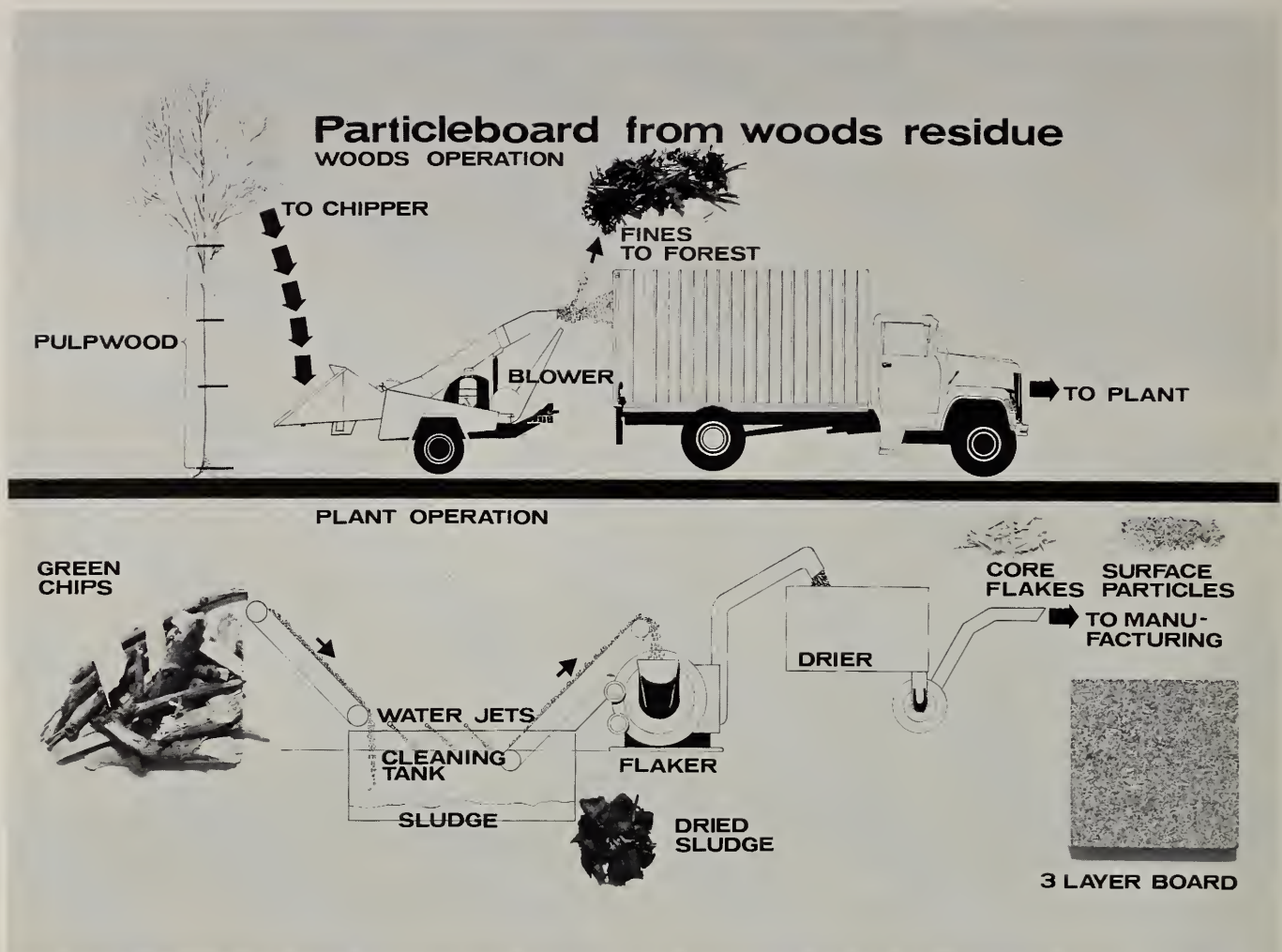
Particleboard Research

A new way of reducing low-quality oak trees to fragments by crushing them between rollers, originated by personnel of the Tennessee Valley Authority, provided raw material for experiments in making particleboard of a strikingly different appearance. The shredded wood was clipped into 3-

inch strands used to make the particleboard. FPL technologists experimented with the raw material supplied by TVA to make both a sheathing-type particleboard and a roof decking bonded with Portland cement. The products provide a possible outlet for much low-grade timber in the TVA area.

Tops of aspen trees commonly left in the forest after the harvest of the tree stems for pulpwood were used in another series of experiments designed to evaluate the top stemwood, branches, twigs, and even leaves as material for particleboard. The object is to develop a use for this material by chipping it in the woods for transport to a mill.

A cylinder-type chipper that can be taken into the woods was obtained for the experiments. The top stemwood yielded chips considered too short for the type of board proposed. The small material, however, was converted to suitable chips. These were put through a commercial flaker that produced material of good size and quality for a process of forming particleboard now widely used in United States mills. In this process, the finer material is automatically segregated and deposited



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Flow chart showing proposed process of converting tops of aspen trees felled primarily for pulpwood.

on the cauls first; progressively coarser material is then deposited until the center of the mat is reached, when the sequence is reversed. Thus both faces consist of fine particles that assure a smooth surface.

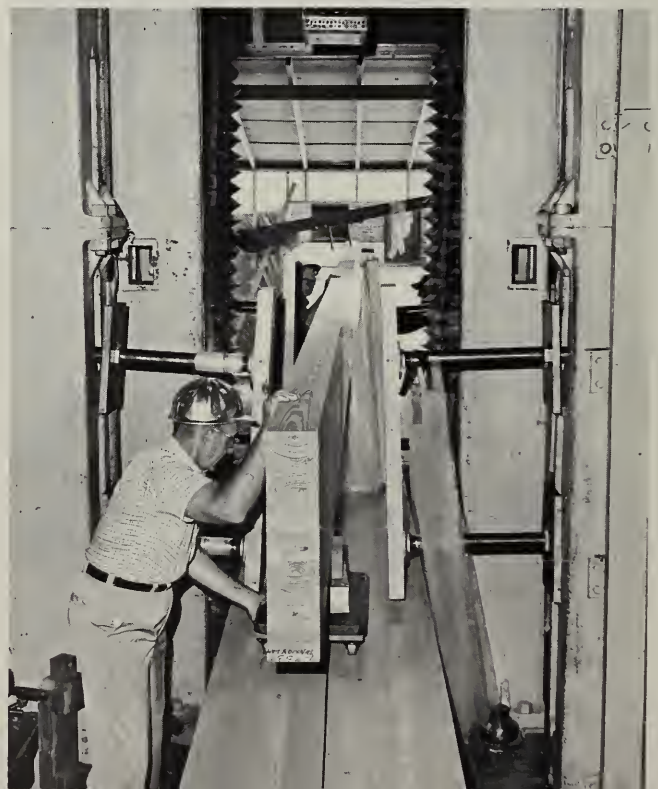
Glued Laminated Timbers

Glued laminated beams, columns, arches, and other structural framing members of buildings have seemingly unlimited size potential. As the industry has expanded, however, the need for re-evaluating design criteria as they relate to large members has become apparent. Since 1962, FPL engineers have been researching the strength properties of beams up to 31½ inches deep and 50 feet long. The need for this work stems from the fact that research in the 1940's was limited to relatively small beams. Since then, industry has begun producing substantially larger bending members, and questions arose as to the applicability of available design criteria to these larger members.

This work has shown that the tension (bottom)

A series of bending tests of large glued laminated wood beams to get data for needed engineering design criteria was completed in 1969.

M 136 997-3





The most effective span for testing framing lumber non-destructively was the object of a study by FPL engineers. Commercial grading machines use a 4-foot span. Here technician Richard K. Geier and research engineer Ivan Orosz study effect of a knot on modulus of elasticity of a 2 x 4.

lamination of large beams is critically important. Recommendations as to restrictions on quality of the wood for this lamination will permit more efficient design. The work was done in cooperation with the American Institute of Timber Construction, which develops industry standards and administers a quality control program.

Containerboard Quality Control

FPL engineers invented a device that permits measurement of linerboards and flute height of single- and multi-wall containerboards simply and inexpensively. Accurate and reproducible results were obtained by operators with minimum training. The device is expected to prove useful to manufacturers in maintaining close quality control and thus to improve the performance of shipping containers made of this corrugated boxboard.

Assembly-Line Pallet Production

From raw log to finished shipping pallet in less than half an hour is the commercial target of a new assembly-line production concept put through pilot-plant trials in 1969. Low-quality red oak logs were rotary-cut into 5/16- or 7/16-inch veneer. From the veneer, slats 4 feet long and 6 inches wide were cut, dried in a hot press in 8 minutes and, hot from the press, glue-laminated to make two- or three-ply pallet deckboards or four- or six-ply stringers.

Under commercial production conditions, two logs would be simultaneously rotary-cut and fed through a continuous roll-press dryer into a continuous glue press to be glued together as a single sheet. This would then be cut to any desired deckboard or stringer width, and stringers of desired thickness built up by further glue laminating. Deckboards and stringers would then be assembled by conventional pallet-making techniques—or, if desired, glued with a mastic adhesive.

Advantages are (1) well-dried pallet stock to assure longer service life with less splitting; (2) use of lower quality wood, since no knot would be continuous through the two-ply piece (specifications now limit knot size to one-third the deckboard width); (3) in the case of adhesive-assembled pallets, a more serviceable product better suited to re-use, especially with automatic stackers, because industrial service tests have shown that adhesive-assembled pallets remain square and true to original dimensions much longer.

Preservative Quality Control

There has been considerable interest in using X-ray fluorescence as a means of analyzing treated wood for certain elements. Where single inorganic elements are present, such as chlorine in pentachlorophenol-treated wood, such analysis is quickly and conveniently made. Where a mixture of inorganic elements is present, serious interferences can occur. For example, if copper, chromium and arsenic are present together, such interferences are serious enough to discredit this direct procedure. Using experimentally determined absorption coefficients for X-rays, a computer program was developed which considerably reduces the errors resulting from such interactions.

Flexibilized Epoxy Adhesive Films

Epoxy resin films in which were incorporated various amounts of flexibilizer to make them more readily deformable under stress were tested in experiments aimed at exploring the possibilities of increasing the versatility of these adhesives. Results showed that it is possible to manipulate the maximum tensile stress and the modulus of elasticity by adding various amounts of flexibilizer.

Films containing a polysulfide flexibilizer showed a capacity for both greater strain at failure and greater work to failure, but results with three others—a mercaptan-terminated polybutadiene, a flexible epoxy, and a polyamide—were inconclusive. All four flexibilizers reduced maximum stress and modulus of elasticity of the formulation in an approximately linear manner with flexibilizer content.

New Peel-Stopping Reaction

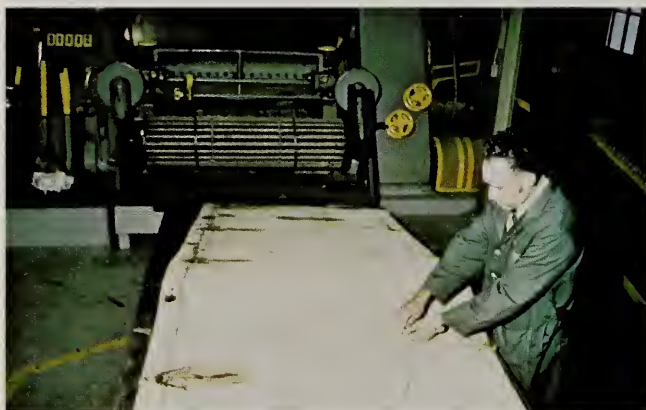
Alkaline pulping can cause 10 to 20 percent

From Log to Pallet in 30 Minutes...

1. Red oak 5/16-inch veneer streams from lathe.
2. Clipper cuts 6-inch slats.
3. Green slats go into press dryer.
4. Hot, dry slats pass through glue spreader.
5. Laminating pairs of slats in cold press.
6. Laminated deckboards are stacked for assembly.
7. Assembling shipping pallet.



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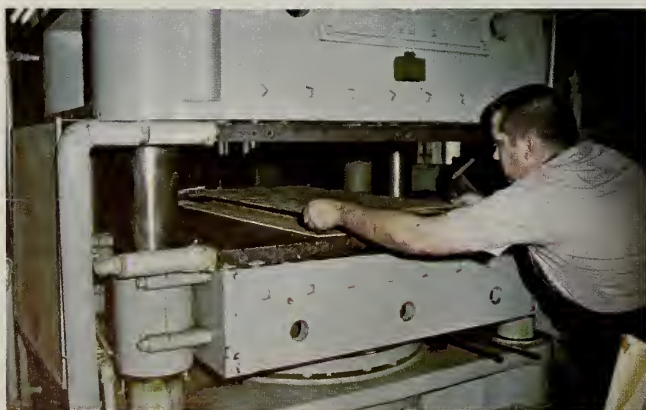
5.



2.



6.



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7.



Chemist Jesse Green operates automated apparatus for identifying small aldonic acid fragments produced during alkaline degradation of carbohydrates.

M 137 797-12

loss of alpha cellulose and up to 35 percent loss of total carbohydrates. This loss is due to a peeling reaction that attacks the reducing end of the cellulose molecule and degrades it to monomeric units by the simple process of stepwise elimination of D-glucose units along the cellulose chain, forming D-glucoisosaccharinic acid. Simultaneously, at high pulping temperatures, there occurs a cleavage reaction of internal glycosidic bonds that results in the formation of new reducing end units, which again undergo the peeling reaction. The reaction is stopped by the formation of more alkali-stable end groups of D-glucometasaccharinic acid.

Many chemical treatments have been advanced over the years that induce some degree of stabilization of the cellulose. They involve generally one of three types of reactions: 1, reduction of the end unit to an alditol with sodium borohydride; 2, oxidation of the end unit to aldonic acids with additives such as sodium polysulfide, sodium hypochlorite, and hydrogen peroxide; and 3, chemical additions to or substitution of the aldehydic functional group with reagents such as hydrogen sulfide, hydroxyl amine, or hydrazine. These reactions predominate in inert atmospheres characteristic of alkaline pulping.

In oxygen, quite different reactions occur. An oxidative carbon-carbon bond cleavage reaction predominates. The stopping reaction mechanism

also differs, consisting of formation of end units of aldonic acids.

In alkaline degradation experiments with cellobiose, a simple model of cellulose, either oxygen-free nitrogen gas or oxygen gas was bubbled through the degradation mixture. Reaction products were collected and analyzed. Products formed in nitrogen were mainly isosaccharinic acid from the reducing end of the molecule, glucose and lactic acid from the nonreducing end. The cellobiose was thus totally degraded. Products formed in oxygen were 3,4-dihydrobutyric acid from the reducing end and glyceric and D-arabinonic acid from the nonreducing end of the cellobiose molecule. Glycosyl-aldonic acids were produced in yields as high as 31 percent, and these aldonic acids have the same stabilizing effect as metasaccharinic acid, which is formed in only 2 percent yield in the nitrogen atmosphere.

Kraft Paper Strength

How forming conditions at the wet web of the paper machine affect the strength and other mechanical properties of kraft papers was the object of an investigation that involved sheet weight and pulp consistence, temperature, and alkalinity. In the quest for faster machine speeds and greater production, these paper machine conditions have

not received the attention they perhaps deserve in view of the fact that kraft papers, especially, are valued and utilized for their superior strength.

Kraft papers were made from both northern pine and southern pine pulps; some of the furnishes with southern pine include some portion of gum kraft pulp.

Of the four variables studied, pulp consistence and sheet weight affected the mechanical properties of papers made from the northern pine pulps. Only sheet weight influenced strength of paper made from the southern pine, and addition of up to 50 percent of gum pulp by weight appeared to have no effect.

Properties and Behavior of Wood and Wood Constituents

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The well-springs of technology require constant replenishment. This calls for a constant flow of new knowledge provided by scientific research. An important segment of FPL's program is devoted to acquisition of new basic knowledge to sustain the applied research and development essential for healthy growth of technology across the broad

spectrum of forest products.

Toward this end, research is maintained on wood's anatomy and microstructure, its physical and mechanical properties, wood-liquid relations, the chemistry of wood and wood constituents, quality evaluations, and biological degradation.

Reared in a greenhouse, these young pines responded to localized application of mechanical energy with marked changes in cambium growth.

M 136 657-7



Growth-Quality Relations

The many factors that affect the production of wood by the tree all likewise influence wood quality as we conceive it. Cell size and shape, cell-wall thickness, width of the annual growth ring, even the kind of fiber produced, are affected by soil nutrients, water, wind, light, temperature, elevation, and topography, and in turn affect wood density, hardness, texture, strength, and other quality criteria. Herein, therefore, is the reason why FPL scientists are delving deeply into the subject of wood growth-quality relations.

Specific research is under way on three major factors, soil-water deficit, wind, and nutrients.

Arkansas-grown loblolly pine was markedly affected by soil-water supplies, it was found in a study of the wood produced. Summer drought affected both volume and dry mass of wood grown, as well as specific gravity, proportion of summerwood in the annual ring, and dimensions of summerwood cells. Fast-growing trees exhibited overall a greater variability in wood structure than slow-growing trees, and younger trees more variability than older trees under similar conditions of soil moisture.

The familiar swaying of trees by the wind generates stress patterns that are thought to stimulate cambial growth. Wind also increases transpiration, raises the temperature gradient between upper and lower portions, and cools bark and leaves. Complex interactions result from these influences of wind. A small exploratory study of the effects of mechanical energy supplied to 10-year-old red pines growing in a greenhouse without swaying them produced solid evidence that cross-sectional area growth is stimulated. Growth was localized at the area of stimulation, permitting close study of the tree's mode of reaction to the applied energy. The experiments are to be continued with the ultimate object of developing information for accelerating growth of superior seedlings capable of producing high-quality wood.

FPL's physiological research on cambial tissue growth as influenced by nutrients and hormones has produced startling new information on cell growth effects and demonstrated that undifferentiated tissue can be induced to develop into plantlets with stem and roots (see 1968 Annual Report).

By means of a technique of "force feeding," the stem of a decapitated ash seedling was kept growing and developed fully differentiated cells. The types of wood cells laid down were manipulated by varying the concentration of hormones—auxins and gibberellins—in the nutrient media. By this technique, extreme variations in cell type compared with normal ash were induced. Eventual object of this work is to learn how biological control stimuli are varied in the root and crown systems of

trees and the degree to which they can be influenced by natural environment stimuli.

Engelmann Spruce Properties

An intensive sampling of Engelmann spruce throughout its range of growth in the United States has essentially confirmed previous strength values for this fifth most plentiful of western softwoods. Fifty specimen logs obtained from randomly selected places from New Mexico to Washington showed only slight changes in average strength and stiffness property values. The findings will be submitted to the American Society for Testing and Materials, which establishes working stresses used by architects, engineers, building code officials, and others concerned with safe and economical design of structures.

The 50 logs used in the re-evaluation were obtained by a random sampling technique never before used over so great a territory. Pack horses and helicopters were needed to bring the logs from remote locations high in the Rocky Mountains. The re-evaluation was undertaken because the original estimates for this species had been based on a much smaller sample from only a few locations. The estimates had been questioned because of reports that strength evaluations of Canadian spruce had shown substantially higher strength and stiffness values.

The more complete sampling raised the accepted specific gravity value for Engelmann spruce from 0.34 to 0.35. The critical stiffness indicator, modulus of elasticity, went up marginally, from 1,280,000 pounds per square inch to 1,290,000 for wood dried to 12 percent moisture content. Comparable Canadian estimates are reported to be 0.40 and 1,550,000.

Bending strength of dry material proved to be somewhat higher at 9,300 pounds per square inch than the previous estimate of 8,700. Compressive strength was down from the previous estimate of 4,770 pounds per square inch to 4,480. Of possible significance to plywood manufacturers was a pick-up in shear strength from 1,030 to 1,200 pounds per square inch.

Fire-Retardant Strength Effects

Bending strength and stiffness of wood are reduced by fire-retardant treatments, according to results of several studies at FPL and elsewhere. The summarized data support currently recommended design values for fire-retardant-treated lumber. Modulus of rupture for structural lumber was reduced on the average about 14 percent, with some variation according to species and type of fire retardant used, when treatment was followed by kiln drying. Loss in modulus of elasticity, an index of stiffness, averaged only 1 percent. The reduction in work to maximum load, which is a measure of

shock resistance, averaged 34 percent for small clear specimens.

Control of Biodegradation

The use of preservative chemicals to protect wood from decay and staining fungi, bacteria, and insects is well established, with a long history of success. Concern over possible adverse environmental effects, however, has caused researchers to explore possible other ways of protecting wood from these natural enemies. One such line of research now under way at FPL is the study of these organisms for possible weak links in their life cycles—points at which their control might be feasible by other means.

One line of investigation involves a search for kinds of fungi or bacteria that might be mutually antagonistic toward or inhibitive of each other. Past studies have shown, for example, that the mold *Trichoderma* could markedly reduce decay in pine bolts and birch logs. The effect was determined to be antibiotic in character.



Pathologist Terry Highley examines fungal growth on (lower jar) untreated wood and (upper jar) dethiaminized wood with thiamine restored. Continued decay resistance of treated wood indicates something else essential to fungus was removed by dethiaminization treatment.

A number of micro-organisms isolated from stored wood chips of various species are being used in studies of the interactions between wood degraders and nondegraders. The object is to learn whether any of the nondegraders are strongly antagonistic to those which degrade wood, and whether such antagonisms might afford a means of controlling degradation of wood products.

An alternative line of research for a nontoxic preservative treatment involves FPL's dethiaminization process. Recent evidence indicates that, even when treated wood regains the thiamine necessary for fungal growth on wood, it remains more resistant to decay than untreated wood of the species. From this the conclusion has been drawn that the treatment also alters or ties up some of the minerals or other nutrients in wood, rendering them unavailable to decay fungi. Various minerals and carbohydrates are being investigated for possible effects of the dethiaminization treatment.

Mechanical Properties of Paper

That properties of paper can be evaluated in engineering terms is a fact clearly emerging from experimental determinations of such mechanical properties as compressive, tensile, and shear strength. Moreover, it has been established that these properties can be markedly varied by such manufacturing controls as those which affect machine direction of the fibers during sheet formation.

Data on the influence of fiber orientation on tensile strength yielded results for handsheets and machine-made paper that proved predictable by a formula originally developed to predict the tensile strength of wood. The formula was successfully used with handsheets at any level of fiber orientation up to and including perfect alinement of all fibers in a single direction.

This work is being continued to develop test methods for measuring the mechanical properties of paper, with the object of eventually replacing empirical test methods now used to ascertain test values peculiar to paper and unrelatable to properties of other materials. These new methods will be essential, it is believed, for automating the papermaking process.

The Rural Economy

It is not coincidental that the boundaries of the Nation's major forest areas and those of some of its worst rural poverty pockets parallel each other rather closely. In many sections, forest-based industries have traditionally consisted of numerous small, geographically and economically segregated business enterprises that chronically suffer from low levels of technological sophistication. The result has often been a product that is made from highly variable raw material in uneconomical volume for restricted local markets by inefficient machines and manpower. The consequences often were low quality, high waste, and economic hardship.

FPL researchers have long been cognizant of this situation and worked to alleviate it, especially in such subject areas as timber harvesting, log and tree grading, small sawmill design and operation, veneer cutting techniques for unused species and small logs, and logging and mill residue utilization. In recent years some of the demonstration and educational phases of this work have been assumed by another branch of the Forest Service, State and Private Forestry. FPL staff members, however, continue to receive many requests for technical guidance, problem trouble-shooting, and the like from S&PF field representatives. Occasionally a scientist is sent to an area for on-the-ground consultation as was the case in Hawaii during 1969. In cooperation with the Small Business Administration and Hawaii's Forestry Department, an FPL sawmill specialist conducted a survey of Hawaiian timber and forest products production and marketing potentials.

Staff members cooperated in another training-type activity long conducted by FPL but in recent years taken over by S&PF. This is the annual Kiln Drying Demonstration, through which thousands have been educated in modern wood seasoning techniques.

Composite panel technology is another subject on which much trouble-shooting is done by FPL for the industry. Frequent cases of production troubles, some of which have resulted in consumer dissatisfaction with furniture, television cabinets, and the like, continue to be referred to FPL specialists for solution. In a single recent year, an

FPL research note that grew out of correspondence on such subjects was used in connection with 3,000 inquiries on related problems. Many manufacturers of such products are located in rural communities dependent on a forest-based economy.

New Product Development

Much of FPL's research on the development of improved products, notably plastic-overlaid plywoods, other composites, structural building components, and shipping pallets, can be utilized by rural industries dependent on locally grown timber. Some instances of this research are described in the section of this Annual Report entitled "Efficiency in Processing and Use." Others, notably the FPL Nu-Frame House incorporating five basic components for walls and roof, have been described in recent FPL publications.

FPL research along these lines is continuing, some of it in cooperation with other Forest Service research agencies and the Tennessee Valley Authority. Pilot plant investigations under way at the Rocky Mountain Forest and Range Experiment Station on overlaying of low-grade lumber are supported by the Small Business Administration. FPL participation includes experimentation with materials to plug knotholes.

Such developments as these can furnish the advanced technology needed to promote successful new business enterprises in rural communities.

A USSR delegation on industrialization of building processes visited FPL October 10, 1969. Shown examining a new roofing component are, left to right: Ivan N. Ditriyev, consulting engineer; Aleksandr M. Tokarev, Minister of Industrial Construction; and Minas G. Chentemirov, construction engineer. Joseph A. Liska, Chief of FPL's Division of Wood Engineering Research, describes the house roofing component with an experimental weather surface of polyvinyl fluoride.

M 137 105-9



Consumer Benefits

The ultimate goal of FPL research is, of course, the satisfaction of consumer needs. The vast outflows of finished products made each year from wood must serve consumers efficiently at moderate cost—whether it be the schoolboy's note pad, the businessman's data punchcards, the homeowner's dwelling or the housewife's kitchen cabinets. In many ways, FPL provides advice and guidance based on research and experience.

It may take the form of letter inquiries—more than 170,000 in 1969; visits (last year they totaled 10,748, from 47 States and 44 foreign lands); meetings of trade and technical organizations both here and abroad; and advice and consultation provided in the drafting of commercial standards, specifications, building codes, grading rules, and other quality-concerned regulations and agreements that affect consumer interest through acts of law, gov-

ernmental regulatory bodies, or private agencies. Whatever the immediate problem involved, FPL specialists attempt to give the soundest technological guidance possible.

An outstanding example of long-time technical guidance was the approval in 1969 of a new softwood lumber standard that for the first time explicitly recognizes the relationship between lumber size and moisture content. The new standard is expected to go into use in 1970. FPL provided much of the technical data that made this forward step possible, through nonvoting membership on the American Lumber Standards Committee, and on a consulting basis to the U.S. Department of Commerce, which promulgates commercial standards.

Other commercial standards on which FPL has been consulted are those for glued laminated lum-

Members of a Wisconsin 4-H Club listen intently as an FPL guide explains a tension testing machine for full-size framing lumber.

M 136 887-8





Causes of certain gluing difficulties which frequently trouble wood products manufacturers were sought by Antonio Sandoval during a year's stay at FPL under sponsorship of the Juan March Institution, a Spanish academic foundation. Sandoval studied the wettability of wood as affected by various surface conditions. With this apparatus he photographs silhouettes of drops of liquid on wood surfaces to study their tendency to spread. Poor wettability can hinder spread of liquid adhesives and cause weak bonds.

M 137 786

ber, softwood plywood, hardboard, particleboard, doors, windows, flooring, insulating board, pallets, and methods of preservative treatment.

FPL's longest service of this nature has been given industry and the public through the offices of the American Society for Testing and Materials. This organization, through its committees of producer, consumer, and general interest membership, draws up many test procedures used to establish and maintain product quality. Among these are some 40 that relate to wood and wood-base materials in construction, and an even greater number related to other aspects of wood use. Twenty FPL staff members are on its committees, some serving as chairmen.

Similar roles are taken by FPL staff members

in the functioning of the Technical Association of the Pulp and Paper Industry, the American National Standards Institute, and the International Standards Organization.

International technological and scientific relations are maintained with many other forest products laboratories, notably through the International Union of Forestry Organizations. FPL Director H. O. Fleischer is chairman of IUFRO's Section on Forest Products and a member of its Permanent and Enlarged Committee, the union's administrative unit. Dr. Fleischer is active in a reorganization of IUFRO now in the planning stage.

From 44 foreign countries came 241 scientists, industrialists and other consulting visitors during 1969. The largest number, 50, came from Thailand—vocational instructors and supervisors in the United States under sponsorship of the Agency for International Development.

In 1969 FPL took on a key consultative role to the Department of Housing and Urban Development by providing technical consultation in the evaluation of industry proposals for new housing concepts in Operation Breakthrough. Further information about this undertaking is given in the section of this Annual Report entitled "Housing Research."

FPL consultative service is also given industry and the general public. Among 1969 visitors were 3,356 classified as "consulting"—that is, they conferred with individual staff members or met at FPL in small groups addressed by staff members. Among organizations meeting here were technical committees and affiliates of the National Forest Products Association, Southern Pine Association, Technical Association of the Pulp and Paper Industry, American Wood-Preservers' Association, National Paint, Varnish and Lacquer Association, the National Woodwork Manufacturers Association, and many others. Their interests ranged from lumber grading to natural finishes for wood in exterior service.

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